2.—THOLEIITE BASALTS FROM CAPE GOSSELIN, WESTERN AUSTRALIA.

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With one plate.

INTRODUCTION.

The following petrographical description of the Cape Gosselin basalts is based upon collections made in that area by Professor E. de C. Clarke, who generously placed them at the writer's disposal. The specimens are preserved in the collections of the Geology Department of the University of Western Australia (Reg. Nos. 5539-5547, 5552, 5555, 10338-10342, 10351-10354).

Cape Gosselin, or Black Point as it is called locally, is about 20 miles east of Cape Leeuwin. The outcrops of basalt at Cape Gosselin are residuals of flows which were possibly of much wider extent. The residuals probably mark the position of the vents or fissures about which extrusion occurred, since there seems to be evidence that the surrounding sediments have been metamorphosed. One specimen of the collection, No. 5543, is a dense black chert, of extremely fine grain size, with thin elongated lenticles of chalcedony between the bedding (?) planes. It has an appearance suggesting that it might have been fused; but it has not been found in situ. A second specimen, No. 5545, is a metamorphosed limestone, and consists of small equigranular crystals of calcite, with thin bands of hematite, more or less parallel to one another, at intervals. The hematite bands may mark original bedding planes.

PETROGRAPHY.

The basalts, as represented in the collection, are olivine-free labrodorite basals, generally similar in character, and with the textures and compositions of tholeiites. In the hand specimen they are grey, crystalline rocks, showing small glassy prisms of plagioclase and occasional dark spots of ferromagnesian minerals, without any suggestion of flow structure.

Under the microscope (Plate 1, Fig. 1-4) they are seen to be microporphyritic, the phenocrysts consisting of stout prisms of plagioclase, about 1 to 2 mms. long, and often strongly zoned. The inner zones have a maximum extinction angle of about 38° in the zone at right angles to (010), indicating labradorite about Ab_{55}, while the outer zones are considerably more acid, and in some instances appear to be andesine, about Ab_{65}. They carry numerous rounded inclusions of apatite. Occasional larger crystals about 3 mms. in diameter possess well marked idiomorphic outlines, but show inclusions of pyroxene and green glass along their cleavage planes. In the specimens with a fine-grained groundmass the plagioclase phenocrysts show a tendency to clot together (Plate 1, Fig. 1).

The pyroxene also tends to microporphyritic, especially in the finer-grained rocks, when it shows twinning parallel to (100); but it rarely shows idiomorphic outline in the coarser-grained rocks, unless adjacent to a patch of glass. Sometimes it forms locally ophitic intergrowths with the plagioclase, but more generally it is moulded about the felspar laths, or intersertal to them. It is lightly brownish to colourless, with $Z \wedge \underline{c} = 40°$ approximately, and has a very low optic axial angle ($2V = 5°$ approximately), so that it is a pigeonite or enstatite-augite. The composition of the pyroxene is variable, as occasional measurements of 2V indicate a more diopsidic character ($2V = 50°$). The pigeonite is the dominant species, however.

The lavas are characterised by the absence of olivine. Only in one slide have small remnants of olivine been seen occasionally.

The textures of the groundmass vary, and the collection might be divided into two groups on a textural basis—dolerites and basalts—but there is a gradation between them. The texture is sub-hyaline and doleritic to intergranular (Plate 1, Figs. 1-4). The minerals of the base are plagioclase (labradorite Ab_{45}), pyroxene (pigeonite), magnetite and glass. The labradorite occurs in small prisms, which grade in size into the microphenocrysts, and the pyroxene is intersertal to it. The glass may appear in one of three forms:—(i) as a brown isotropic glass, which consists of a felspathic material crowded with minute grains of iron-ores, and is the common type; (ii) as a green chloritic, and weakly birefringent material, filling cavities; and (iii) occasionally as a clear yellow material. Iron ore forms fairly coarse crystals throughout the groundmass, and is sometimes skeletal in a curious pattern (Plate 1, Fig. 4), the diagonals and the rim of the crystals having developed, while the intermediate parts of the crystals remain unfilled.

The collection includes a vein of calcite through the basalt, but the rocks themselves are free from zeolites or calcitic material. The calcite is probably derived from the metamorphosed limestone referred to previously.

An analysis of a typical tholeiite gives the following composition:—

	1.	2.	3.	4.
SiO_2	51·14	49·42	47·88	50
Al_2O_3	14·56	14·95	14·22	13
Fe_2O_3	4·05	1·38	1·73	13
FeO	7·04	10·76	12·36	
MgO	6·25	6·16	6·35	5
CaO	10·15	9·85	10·23	10
Na_2O	3·96	2·70	2·47	2·8
K_2O	0·58	0·72	0·51	1·2
H_2O + 110 ...	0·54	0·77	0·23	
H_2O — 110 ...	1·35	0·09	0·07	
CO_2	0·05	*nil*	*nil*	
TiO_2	0·01	1·95	2·95	
MnO	0·16	0·47	...	
Cl	*nil*	...	0·08	
S	*nil*	0·26*	0·08*	
BaO	*nil*	...	tr.	
Total	99·86	100·03	99·71	

* FeS_2.

1. Tholeiite, from columns at the western end of the outcrops, Cape Gosselin (No. 10353). (Analyst—A. B. Edwards).

2. Quartz-dolerite, sill or flow, Irregully Creek, Upper Ashburton River, N.W. Division (*Bull. No. 67 Geol. Surv. Western Australia*, p. 32, Analysed Specimen No. 7728). (Analyst—H. Bowley.)

3. Amphibolite, Bunker Bay, near Cape Naturaliste (*Proc. Lin. Soc. N.S.W., li.*, (4), p. 625, 1926).

4. Composition of Tholeiite Magma Type, after W. Q. Kennedy, *Amer. Journ. Sci. vol. 25*, 1933.

Norms.

	1.	2.
Q	...	...
Or	3·45	4·45
Ab	31·65	23·06
An	19·12	26·41
Ne	...	...
di	25·26	15·65
hy	2·34	18·64
ol	9·65	3·86
mg	5·88	2·09
il	0·03	3·65
ap	0·03	1·28
cal	0·10	...
pyr	...	0·26

The analysis is remarkable for its low titania content, but otherwise approximates closely in composition to the tholeiite magma, as defined by Kennedy.(9). It is quite distinct from the olivine-basalts of the Eastern States, and from the much older Antrim Plateau basalts of the Kimberley District, which are fine-grained felspathic rocks, possibly related to the mugearites. The nearest approach to it chemically among the analyses of Western Australian rocks is a quartz-dolerite from the Ashburton River(3) but this carries quartz, orthoclase, hornblende and biotite in addition to labradorite and augite. Also similar in bulk composition is an amphibolite dyke from Bunker Bay, near Cape Naturaliste(5), which consists of brown hornblende, rhombic pyroxenes, basic plagioclase and ilmenite. It is thought, however, by Saint-Smith(2) to be a derivative of the ancient granites of the Cape Naturaliste region.

On account of the relatively high soda content recorded in the analysis, the Cape Gosselin basalt appears undersaturated in the norm, rather than tholeiitic (saturated). The large amount of soda leaves less silica available in the calculations. This increases the amount of albite and diopside in the norms, at the expense of the anorthite and hypersthene. Magnesia, which with a lower soda content would appear as hypersthene, has to be calculated as olivine. With a somewhat lower soda content the norm would indicate the typical tholeiitic characters which the rock itself possesses. Such a norm is provided by the quartz-dolerite (Analysis 2), in which the only outstanding chemical differences from the Cape Gosselin analysis are the titania and soda percentages.

Tholeiites are rare among the records of Australian basalts. The only occurrence known to the author is a tholeiite dyke from Kangaroo Island, South Australia, which has been described by Tilley(7), and is regarded by him as associated with the enstatite-basalts of that island(1). Olivine-free basalts have been described from Queensland by Richards(4 6), but they do not appear to be true tholeiites.

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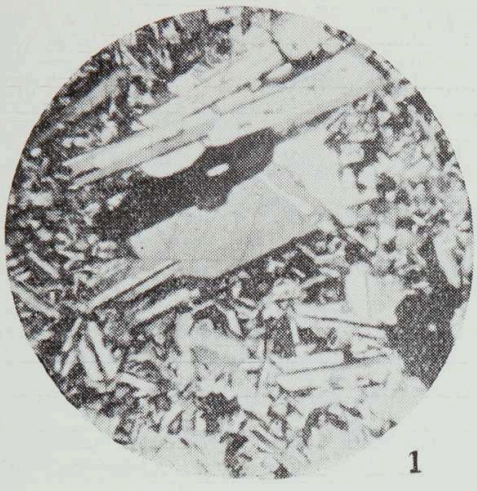

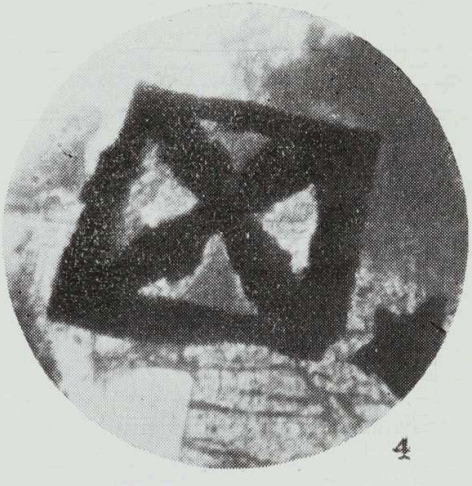

PLATE 1.

1. Clot of zoned plagioclase phenocrysts in a fine-grained, sub-hyaline groundmass. Crossed nicols, X 20.
2. Doleritic textured tholeiite, showing intergrowth of plagioclase and pigeonite, with dark intersertal glass. Ordinary light, X 65.
3. Groundmass of intergranular tholeiite. Ordinary light, X 67.
4. Skeletal crystal of magnetite, from groundmass of tholeiite. Ordinary light, X 300.